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ThM4 (Invited)
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Optical Label Swapping of Payloads up to 40 Gb/s Using an Orthogonally Modulated Label

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Abstract: Label swapping and multi-hop transmission are experimentally demonstrated for payloads at 10 and 40 Gb/s using orthogonal IM/FSK, IM/DPSK and RZ-DPSK/IM labeling.

1. Introduction

Optical label switching (OLS) has been proposed as an efficient technique to route and forward Internet Protocol (IP) packets transparently in the optical domain. For this purpose, a low speed label that can easily be processed electronically at the network nodes is associated to a burst of aggregated IP packets at an ingress edge node of a label switched network. Within the network, the label information is read, processed and updated, a process known as label swapping, until the burst reaches the desired egress edge node. A number of technologies implementing this general concept are currently being investigated, including time-serial labeling and subcarrier multiplexing [1]. Exploiting simultaneously two dimensions of the light field, such as the intensity and the phase or frequency, has been suggested to modulate both payload and control data on the same optical carrier [2]. Such an "orthogonal modulation" labeling method is currently experiencing a renewed interest [3]. In this paper, we present some of our recent results on orthogonal labeling of payloads at 10 and 40 Gb/s. We report label swapping of a 10 Gb/s intensity modulated (IM) payload with a frequency shift-keying (FSK) label in a semiconductor optical amplifier (SOA) interferometric wavelength converter. We also show how label switched networks could be upgraded to 40 Gb/s by taking advantage of the attractive properties of the differential phase shift-keying (DPSK) format, used in conjunction with an IM label.

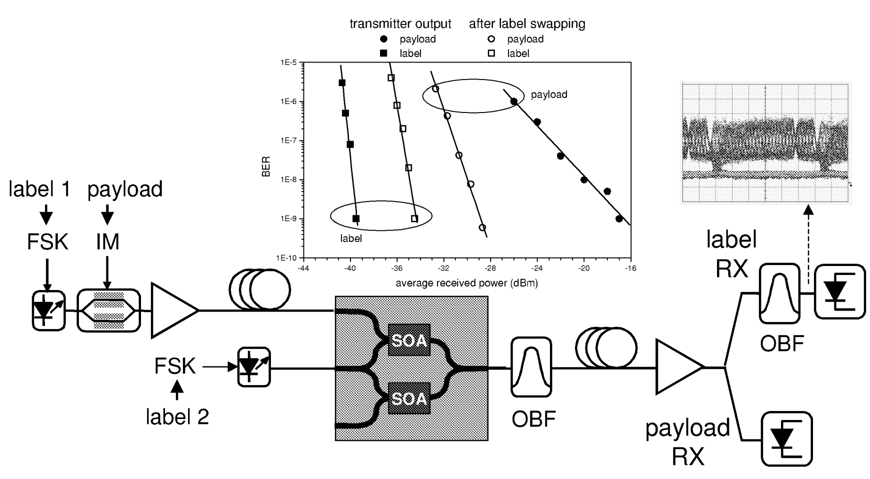

Fig. 1: Principle of label swapping for IM/FSK labeling. The insets show a typical demodulated FSK label eye diagram for a 312 Mb/s label associated with a 10 Gb/s IM payload, as well as BER performance of the label swapping node obtained with a 156 Mb/s FSK label and 10 Gb/s IM payload.

2. IM/FSK label swapping at 10 Gb/s

Fig. 1 illustrates the basic principle of orthogonal IM/FSK labeling. Direct current modulation of a distributed feedback (DFB) laser [4] or of the phase section of a grating assisted coupler sampled reflector (GCSR) widely tunable laser [5] is achieved at 156 Mb/s with the label data. An external Mach-Zehnder modulator is then used to intensity modulate the payload information at 10 Gb/s with a low extinction ratio. Note that some coding techniques can mitigate the finite extinction ratio requirement for the payload [6]. At the network node, the FSK label is erased in an interferometric SOA wavelength converter based on cross-phase modulation. If the probe signal is FSK modulated with the new label information, the new label will be transferred to the wavelength converted payload. The FSK label, with a typical tone spacing of 10-20 GHz, is demodulated by an optical bandpass filter (OBF) before direct detection. As can be seen in the inset of Fig. 1, error free performance is obtained for the payload after both transmission over a 44 km dispersion compensated standard single mode fiber (SMF) span and label swapping. The sensitivity of the payload is even improved due to the regenerative nature of the wavelength converter. Different sensitivities are obtained for the original label and the swapped label due to the different FSK sources (DFB or GCSR laser) and tone spacings (20 or 10 GHz, respectively). The quality of the label swapped signal was sufficient to allow propagation over a second 40 km SMF span, yielding a penalty of less than 0.5 dB for the payload.

3. Optical labeling of DPSK signals at 40 Gb/s

Differential phase-shift keying has also been shown to be a possible option to perform optical labeling of a 10 Gb/s payload [7]. However, at 40 Gb/s one might want to take advantage of the attractive properties of the DPSK format for transmission of the payload (due to benefits of balanced detection in terms of sensitivity and burst mode operation, as well as resilience against optical fiber nonlinearities). Furthermore, the practical implementation of DPSK detection is eased at high bit rates and the sensitivity to laser phase noise is significantly reduced. Using an IM label with a DPSK payload therefore appears as a natural choice. We have performed transmission of a 40 Gb/s RZ-DPSK payload with a 2.5 Gb/s IM label, as illustrated in Fig. 2 [8]. At the network nodes, label erasure can be achieved by modulating the labeled data with the inverted detected label. We have shown that IM labeling causes 2.3 dB penalty on the RZ-DPSK payload after transmission over a 50 km dispersion compensated SMF span, while the transmission penalty is less than 2 dB for the label. The use of balanced detection is expected to result in improved performance for the payload.

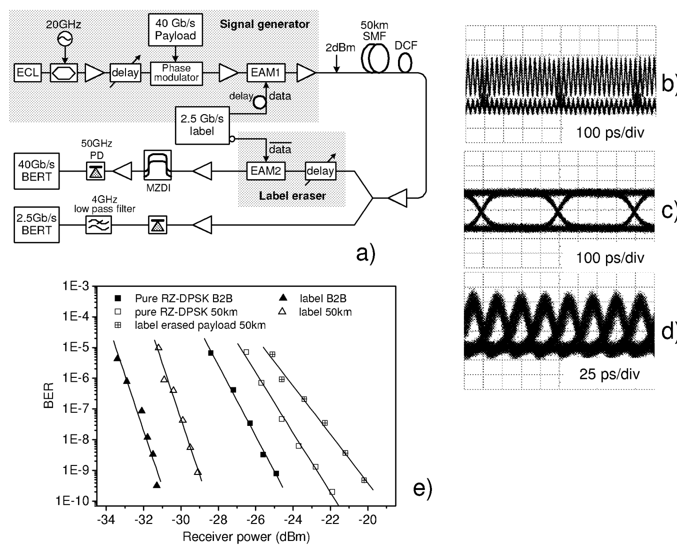

Fig. 2: Experimental set-up for the demonstration of 40 Gb/s RZ-DPSK/IM labeling (a). Eye diagram of the detected IM label before (b) and after (c) low-pass filtering, and of the demodulated RZ-DPSK payload after label erasure (d). BER performance of the label and payload considered individually, as well as after transmission and label erasure of the orthogonally modulated signal (e).

4. Conclusion

We have demonstrated the feasibility of orthogonal modulation labeling for payloads at 10 and 40 Gb/s. At 10 Gb/s, FSK labeling of an IM payload has been shown to be a promising candidate for the implementation of optical label switched networks. Label swapping has been achieved using a SOA interferometric wavelength converter. The potential of RZ-DPSK/IM labeling, exploiting the benefits of DPSK modulation for the payload, has also been demonstrated at 40 Gb/s.

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